

IMPACT, A TOOL SUITE FOR CREW HEALTH AND PERFORMANCE SYSTEM TRADE ANALYSES AND DECISION SUPPORT- TRANSITION TO OPERATIONS



Informing Mission Planning via Analysis of Complex Tradespaces (IMPACT)

Presented at the 2023 HRP Investigators Workshop by:
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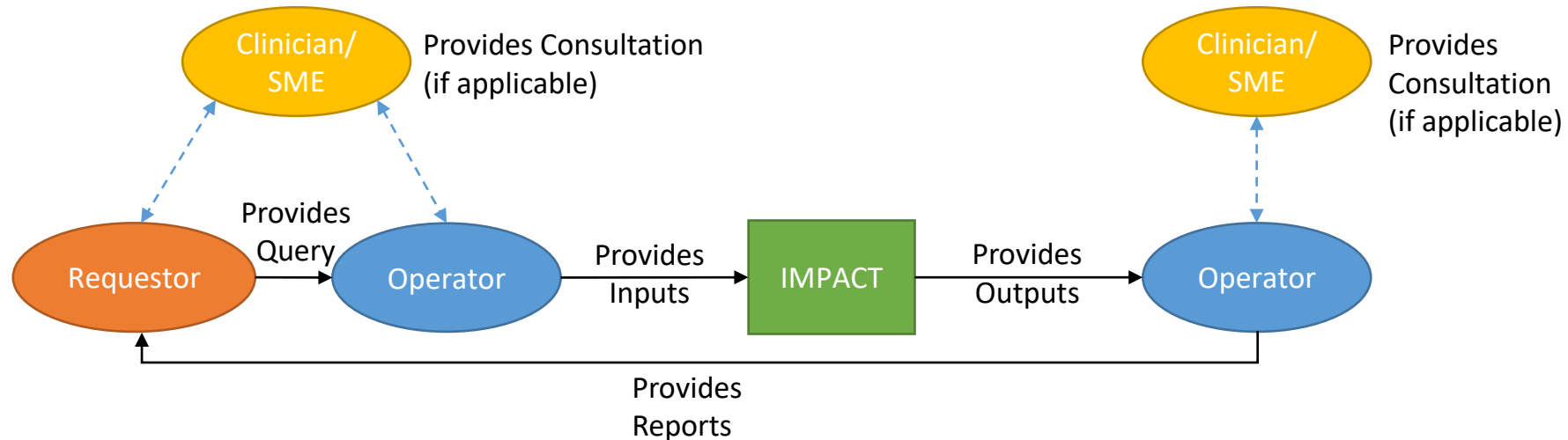
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“Expanding the Boundaries of Space Medicine and
Technologies”

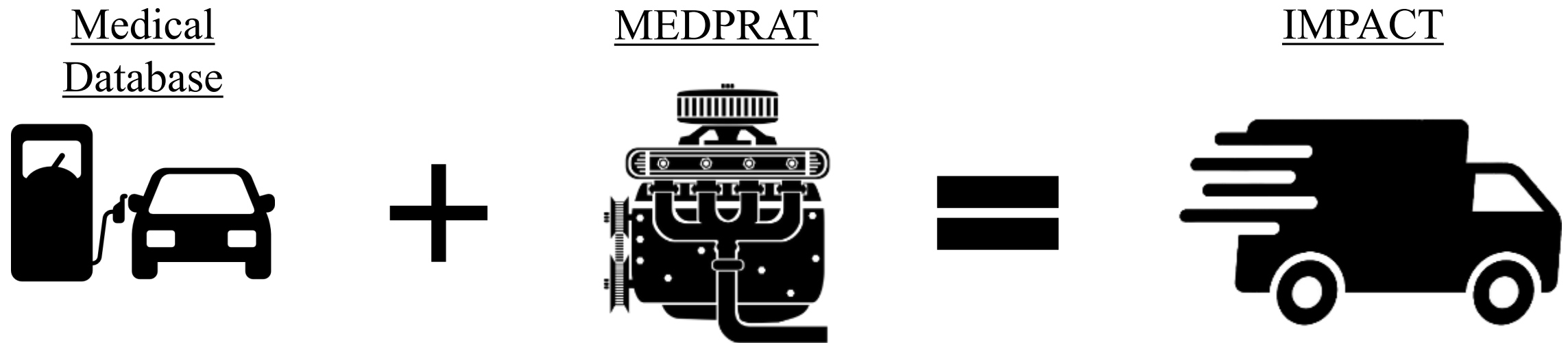
NASA Exploration Missions Need Tools to:

- Provide a data-driven means to inform human health and performance risk mitigation within resource-constrained exploration mission development
- Enable systematic trade studies to evaluate options



Informing Mission Planning via Analysis of Complex Tradespaces

- Probabilistic Risk Assessment (PRA) model and Tradespace analysis tool suite to inform an exploration medical system
- Successor to IMM
- IMPACT v1.0 Transition to Operations (TTO) FY23

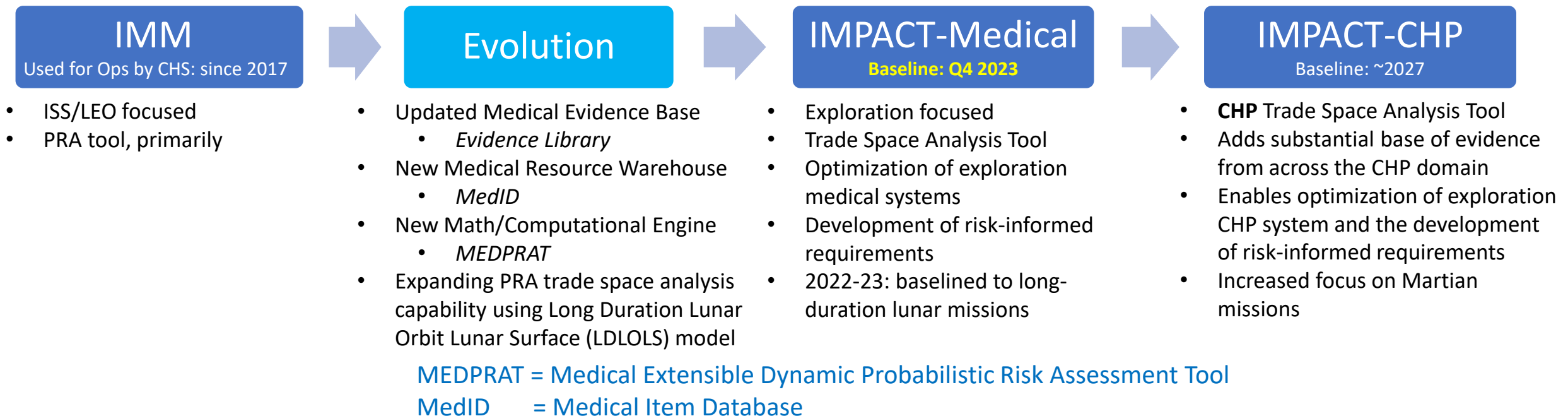


IMPACT is an Evolution of PRA into a Trade Space Analysis Tool

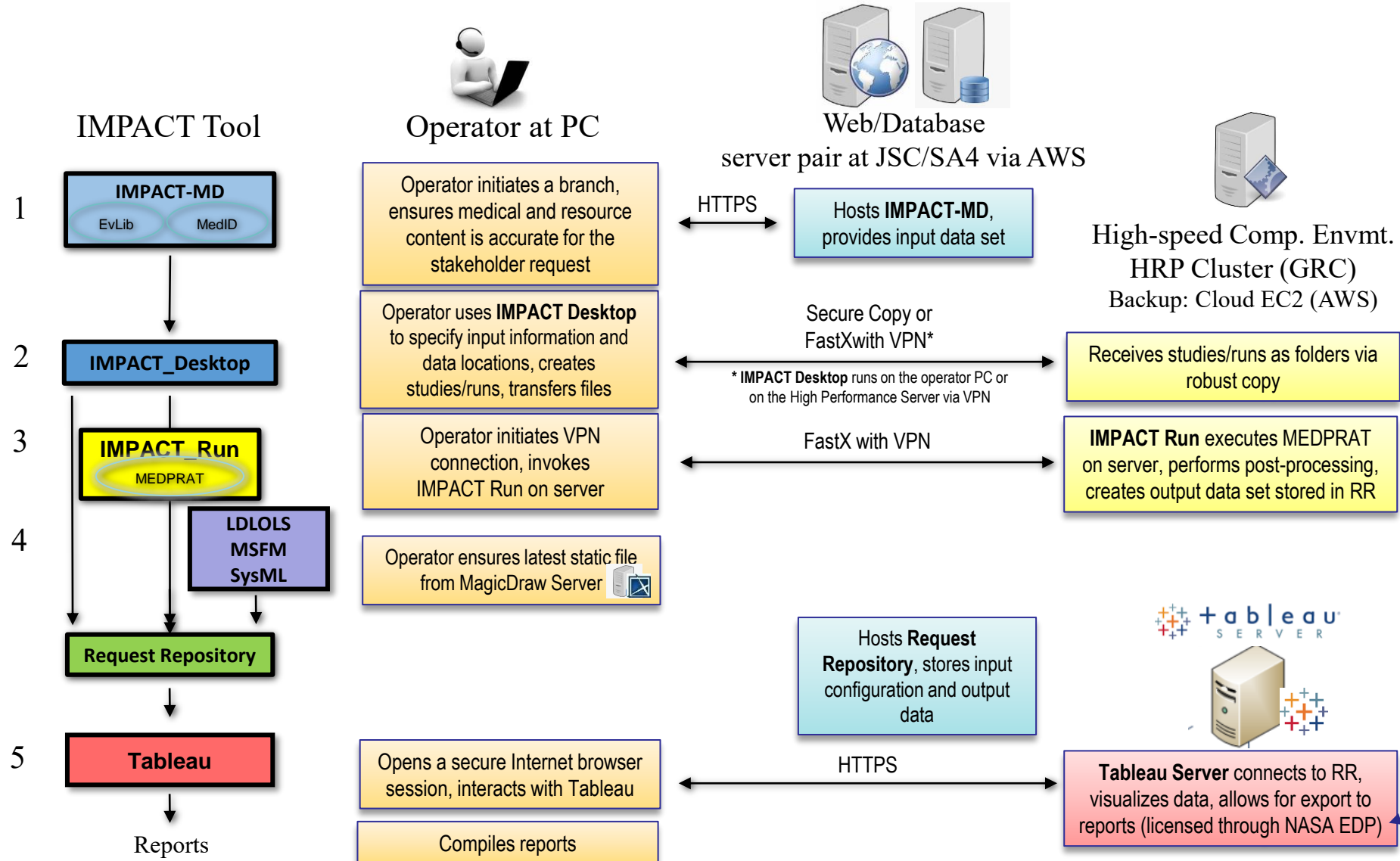


IMPACT: Integrated computational tool to perform complex trade space analysis and enable decision-making

- Supports data-driven and evidence-based decision-making throughout the entire mission life cycle
- Quantifies the effects of specific design decisions on medical and crew health and performance risks



Information flow diagram for IMPACT 1.0



Recent change

Updated evidence base for the Exploration era: IMPACT-MD



HRP-48036

- **IMPACT Medical Database (IMPACT-MD)** represents a significant leap in content versus the legacy dataset used by IMM (presented to HSRB JUL21)
 - **Baselined to Exploration** and deep space environments
 - **Expanded IMPACT condition list (ICL)**
 - » 120+ conditions vs. 100 for IMM
 - » More Exploration-focused conditions (e.g., lunar dust exposure))
 - **Well-vetted, published methods** for gathering evidence base
 - » See Evidence Library Methods paper (HRP-48036) →
 - » And Med ID Methods paper (IMPACT-PRO-0027)
 - **Medical capabilities** are considered, capturing complex relationships among medical resources in **treatment clusters**
 - **Task-focused impairment model** (cf. J. Stuster, NASA/CR-2018-220043)
 - » Task time lost (TTL) replaces Quality Time Lost (QTL)

Exploration Medical Capability Evidence Library Methods

Verify this is the correct version before use

<https://hrp.sp.jsc.nasa.gov/HRP%20Pages/HRP%20Document%20Management%20System.aspx>

January 2021
Baseline



National Aeronautics and Space Administration
Lyndon B. Johnson Space Center

[Evidence Library Methods White Paper](#)

IMPACT v1.0 uses MEDPRAT as its computational engine



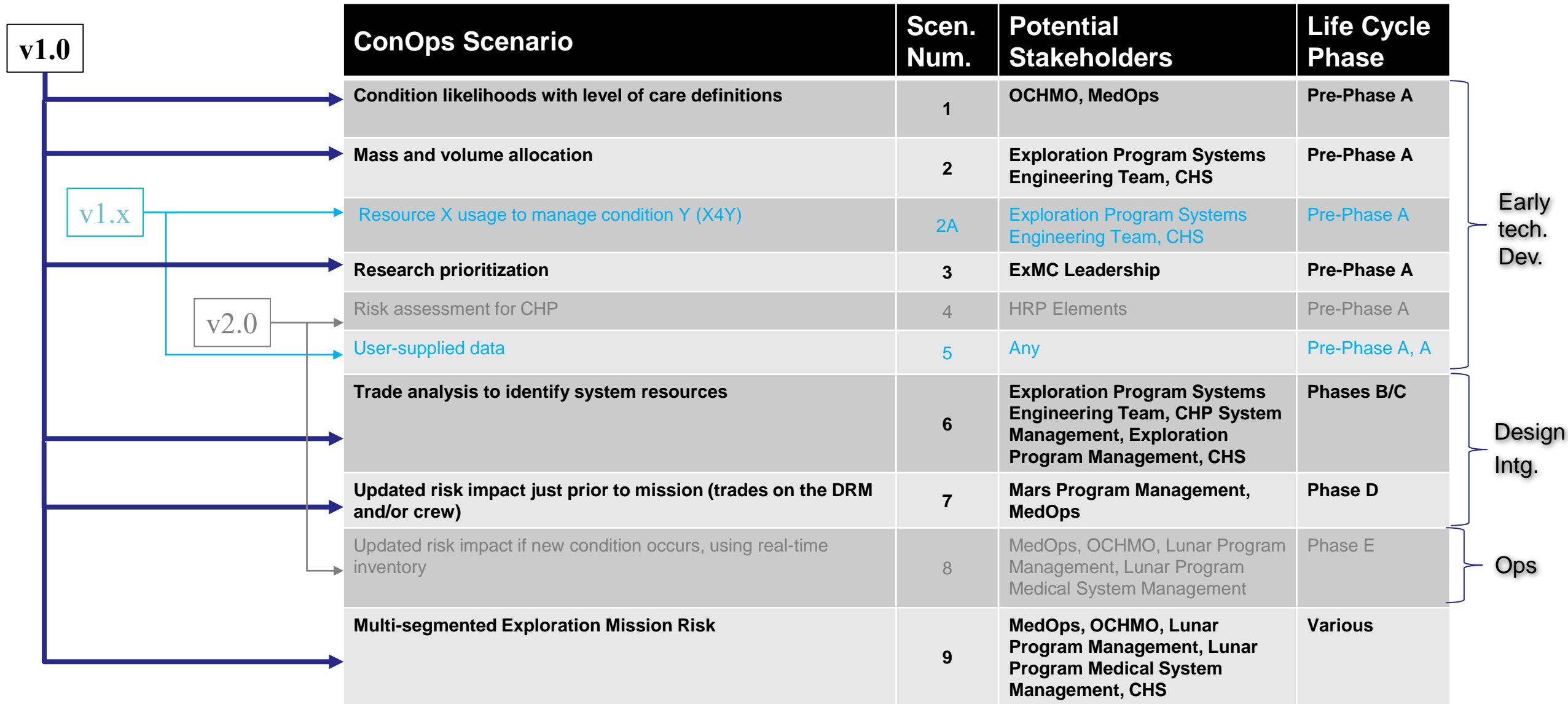
- **MEDPRAT (Medical Extensible Dynamic Probabilistic Risk Assessment Tool) Computational Engine for IMPACT v1.0**
 - **Faster execution speeds** for simulations and optimizations (most simulations take minutes or hours, not days)
 - **Enhanced algorithm supports weighted multi-factor optimizations (e.g. mass and volume simultaneously)**
 - **Supported risk factors: Loss of Crew Life (LOCL), Task Time Lost (TTL), Removal to Definitive Care (RTDC)**
 - Also computes Crew Task Index (CTI), a task-oriented analog to the old Crew Health Index (CHI) from IMM
 - **Supports clustering** of resources, including during optimizations
 - **Supports segmented missions** with multiple vehicles having different medical systems
 - Reporting can be by overall mission or by individual segments
 - **Supports expanded list of mission activities**
 - Multiple EVA types (space-based, surface ops)
 - Split crew members across segments
- **MEDPRAT already supports features intended for later IMPACT releases (v1.x)**



- **IMPACT enhances PRA with trade-space analysis capability**
 - **System trades** (i.e., medical capabilities and system requirements) vs. simple lists of medical items
 - Integration with a **medical system foundation model** (LDLOLS for v1.0)
 - User-supplied models can be integrated with some effort
 - **Research prioritization:** IMPACT can estimate effects on medical risks of using promising new technologies for managing conditions vs. mission constraints while considering other figures of merit
 - Competing research proposals can be compared based on their effects on overall medical risk posture

Tradespace analysis allows NASA to analyze the complex resource, costs and provisioning involved in large projects with multiple stakeholders and multiple objectives. It informs optimization among multiple variants with strong interdependencies

Potential Stakeholders of IMPACT mapped to Concept of Operations (ConOps, HRP 48020A) Use Case Scenarios



IMPACT Supports Complex Design Reference Missions



- Segmented missions with different carriers
- Complex EVA schedules, multiple types and
- Segments can be crew-specific

Segment Schedule

Data Identifier	Crew Label	Segment Name	Type	Start Time	End Time	Period
DEMO_LD125_4Cases_fixed 60kg_Opt_for_NoAntibiotics SimResults	ALL	GWAS	SAS	180	Null	Null
		HLS	GENERAL	180	202	Null
		MISSION	MISSION	0	365	Null
		Orion_Inbound	GENERAL	202	365	Null
		Orion_Outbound	GENERAL	0	180	Null
		RTDC_Window	RTDC	0	1	6
		SAS	SAS	0	Null	Null
		SAS_LunarDeparture	SAS	202	Null	Null
	CREW1	Lunar_EVA	EVA	181	Null	2
	CREW2	Lunar_EVA_Hab	EVA	181	Null	2
		Microgravity_EVA	EVA	50	Null	5
	CREW3	Lunar_EVA	EVA	181	Null	2
	CREW4	Lunar_EVA_Hab	EVA	181	Null	2
		Microgravity_EVA	EVA	50	Null	5

Notional

Crew

Data Identifier	Crew Label	Sex	Contacts	Crowns	Pregnancy	
DEMO_LD125_4Cases_fixed 60kg_Opt_for_NoAntibiotics SimResults	CREW1	male	No	Yes	No	■
	CREW2	male	No	No	No	■
	CREW3	female	Yes	No	No	■
	CREW4	female	No	Yes	Yes	■

IMPACT v1.0 Use Cases – Condition Occurrence Probability



- For any condition, identify probabilities of
 - No Occurrence
 - 1 or more occurrences
 - Best/worst case
- Tabular or graphical display
- Extensive sorting and filtering capabilities
- Examine data for the whole mission or by individual segments

TABULAR By Total Mission (2)

Condition Name	Data Identifiers	Mission	Prob Zero
ICL121_Spaceflight Related Relationship Problems	Run-Analysis-100 Study1 SimResults	Total Mission	0.000%
ICL18_Bhp - Sleep Disturbance	Run-Analysis-100 Study1 SimResults	Total Mission	0.004%
ICL78_Rash, Spaceflight Associated	Run-Analysis-100 Study1 SimResults	Total Mission	0.514%
ICL63_Headache	Run-Analysis-100 Study1 SimResults	Total Mission	0.598%
ICL82_Respiratory Tract Infection - Upper	Run-Analysis-100 Study1 SimResults	Total Mission	1.424%
ICL49_Eye Irritation/Corneal Abrasion/Ulceration	Run-Analysis-100 Study1 SimResults	Total Mission	1.449%
ICL86_Skin Abrasion	Run-Analysis-100 Study1 SimResults	Total Mission	1.637%
ICL48_Eye Foreign Body	Run-Analysis-100 Study1 SimResults	Total Mission	3.872%
ICL104_Sprain/Strain - Upper Extremity	Run-Analysis-100 Study1 SimResults	Total Mission	4.959%
ICL101_Sprain/Strain - Back	Run-Analysis-100 Study1 SimResults	Total Mission	6.497%

GRAPHICAL BY Segment

Condition Name	Data Identifiers	Segment Name	
ICL11_Barotrauma (Ear/Sinus Block)	Run-Analysis-100 Study1 SimResults	EVA	64.3644% 34.9229%
ICL37_Ebullism	Run-Analysis-100 Study1 SimResults	EVA	99.9959%
ICL39_Eva Related Decompression Sickness	Run-Analysis-100 Study1 SimResults	EVA	87.3343%
ICL40_Eva Related Dehydration	Run-Analysis-100 Study1 SimResults	EVA	99.9999%

Display Format
Graphical By Total Mission and Segments

Sort Field
Worst Case

Sort Order
Descending

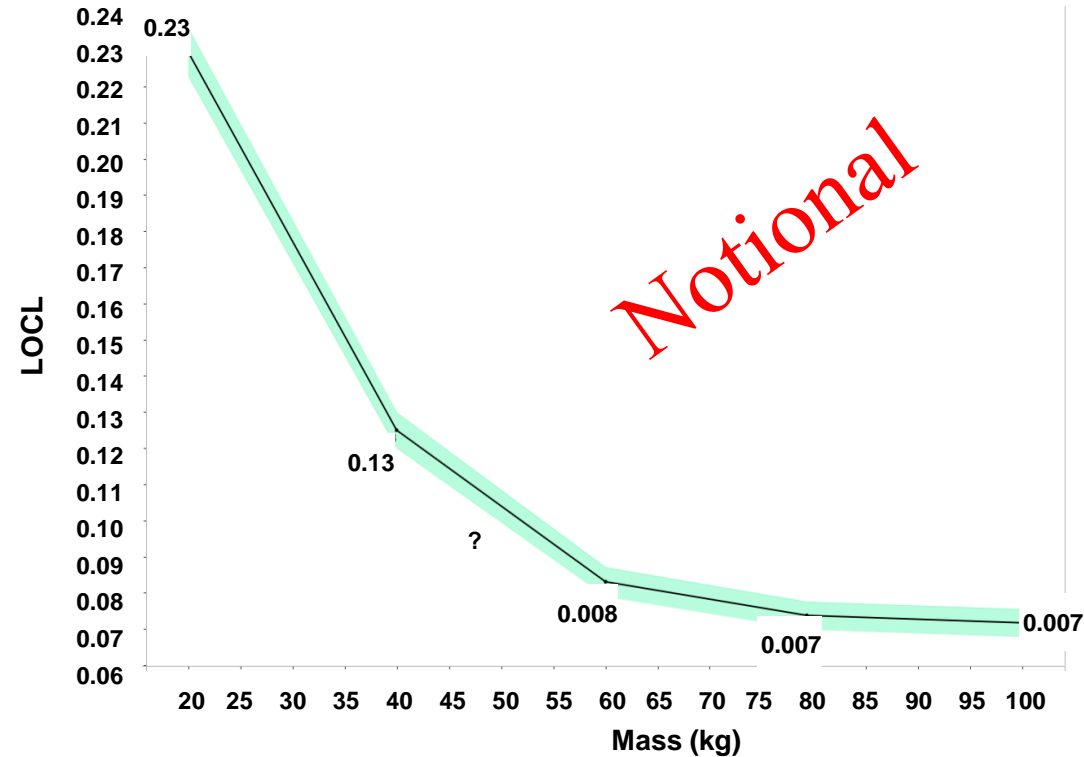
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Legend:
■ Prob One Or More Worst Case
■ Prob One Or More Best Case
■ Prob Zero

IMPACT v1.0 Use Cases – Mass or Volume Allocation vs. Medical Risks (Single-segment optimization only in v1.0)



- Optimize over a range of allocation targets
- Create mass or volume vs. risk curves to identify “inflection points”



- Identify specific differences between the contents (Resource Quantity) of optimized medical sets at 60kg vs. 40kg
- Determine how often specific resources are exhausted at various allocations

Resource Name	Data Identifier	Lockdown	Segment Name	Resource Exhaustion Frequency	Resource Quantity
Wound Care - Suture - Absorbable	Scenario_2_Mass_Volume_Curves VaryMass_LOCL	40kg	Mission	98.044%	0
3.0	Mass_40_kg				
	Scenario_2_Mass_Volume_Curves VaryMass_LOCL	60kg	Mission	55.322%	3
	Mass_60_kg				

<60% threshold of acceptability,
User-selected

IMPACT v1.0 Use Cases – Mass/Volume Allocation vs. Medical Risks

Post-processing to determine impacted requirements during trade space analysis



- IMPACT-MD provides a resource to capability mapping
- Identifies the medical capabilities impacted by an exhausted resource

Wound Care - Suture - Absorbable 3.0 Baseline

Edit Change Log Close

Overview Associated Conditions 14 Associated Capabilities 6

CAPABILITIES

Capability

CP2 - Procedure - Dental - Oral Sutures

CP2 - Procedure - Emergency Burr Hole

CP2 - Procedure - Wound Care - Control Bleeding

CP2 - Procedure - Wound Care - Control Significant Bleeding

CP2 - Procedure - Wound Closure - Multilayer

CP2 - Procedure - Wound Closure - Single Layer

Notional

- Tableau provides a visualization of the mapping of any capability to its medical system requirements
- For this example, seven (7) medical system requirements become impacted when the capability “CP2 – Procedure - Wound Care – Control Bleeding” is impacted

	Requirement ID	Requirement Name	Requirement Text	Requirement Rationale	Capability Name
1	L4-Lunar-MedSys-0002	L4-Lunar-MedSys-0002 Provide crew physical access to medical inventory	The Habitat CHP Medical System shall enable crewmembers physical access to medical inventory.	The Habitat CHP Medical System needs to enable crew access to inventory. This requirement focuses on providing the crew physical access to inventory as a complement to information accessed through medical records.	CP2 - Procedure- Wound Care - Control Bleeding
2	L4-Lunar-MedSys-0003	L4-Lunar-MedSys-0003 Prepare habitat for medical activities	The Habitat CHP Medical System shall enable crewmembers to prepare the habitat for medical activities.	The Habitat CHP Medical System needs to provide the capability to prepare the Habitat for medical activities. Preparation of the Habitat for medical purposes involves crew activities such as creating appropriate volumes for medical use.	CP2 - Procedure- Wound Care - Control Bleeding
3	L4-Lunar-MedSys-0029	L4-Lunar-MedSys-0029 Enable wound care	The Habitat CHP Medical System shall provide capabilities to enable wound care.	The Habitat CHP Medical System needs to provide capabilities (e.g., tools, technology, skills, medications) to assist the caregiver in performing procedures that support the management of wounds (e.g., control bleeding, volume for medical use).	CP2 - Procedure- Wound Care - Control Bleeding
4	L4-Lunar-MedSys-0083	L4-Lunar-MedSys-0083 Provide crew role-based privileges	The Habitat CHP Medical System shall provide for different crew roles and corresponding privileges to access medical data.	The Habitat CHP Medical System needs to support different crew access privileges. Roles of crew members in medical activities are required to protect personal information and provide privacy and security to the medical data.	CP2 - Procedure- Wound Care - Control Bleeding
5	L4-Lunar-MedSys-0098	L4-Lunar-MedSys-0098 Treat patient	The Habitat CHP Medical System shall provide capabilities for the treatment of the patient.	The Habitat CHP Medical System needs to provide the capability to support the treatment of medical conditions. This ability to treat medical conditions is critical to ensuring adequate and rapid delivery of medical care for patients.	CP2 - Procedure- Wound Care - Control Bleeding
6	L4-Lunar-MedSys-0205	L4-Lunar-MedSys-0205 Provide preventive care	The Habitat CHP Medical System shall provide preventive care capabilities for all crewmembers.	The Habitat CHP Medical System needs to provide preventive medical care capabilities. Preventive medical care services are intended to help crew remain healthy by detecting health-related problems early while giving them medical data.	CP2 - Procedure- Wound Care - Control Bleeding
7	L4-Lunar-MedSys-0237	L4-Lunar-MedSys-0237 Provide advanced trauma life support (ATLS) for a patient	The Habitat CHP Medical System shall provide advanced trauma life support (ATLS) for a patient following an unplanned traumatic medical injury (e.g., trauma).	The Habitat CHP Medical System needs to provide advanced trauma life support (ATLS) capabilities for the diagnosis and treatment of any crewmember following an unplanned traumatic medical injury (e.g., trauma).	CP2 - Procedure- Wound Care - Control Bleeding

Other use cases are demonstrated in the Backup Slides

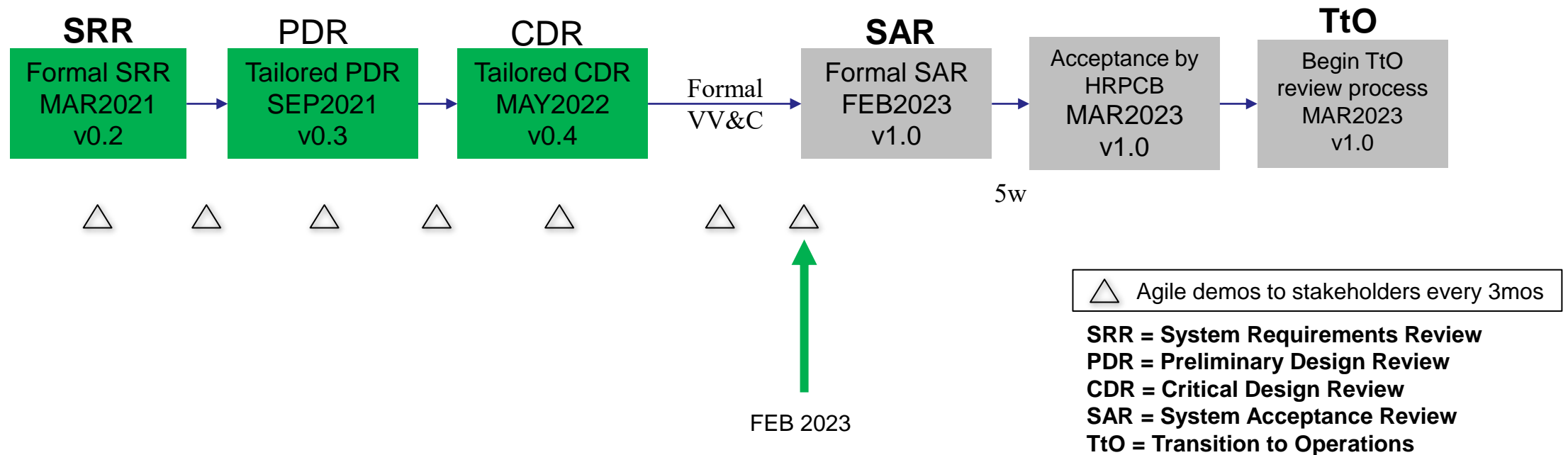


- **Comparing Medical sets directly**
 - Investigate the effect of changes to a Baseline medical set on medical risk
 - Can forcibly include or exclude items or capabilities in a trade space analysis (e.g., ultrasound)
- **Mission trades**
 - Mission attributes can be trade study variables
 - Quantitative
 - Mission Duration
 - Number of EVAs
 - Qualitative
 - Segments added, deleted, reordered
 - Crew attributes, pre-existing conditions

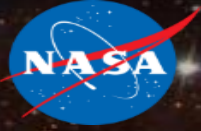
IMPACT Milestone Review Process with 5-month schedule move



- IMPACT design/development uses a modified Agile strategy with frequent customer demos to demonstrate the design
- Tailored PDR and CDR to demonstrate project maturity level commensurate with the traditional SE milestone
- A panel participates in both the formal and tailored reviews
 - Panelists represent all major stakeholder groups for IMPACT identified in the IMPACT ConOps
 - The panel is also invited to the software demos



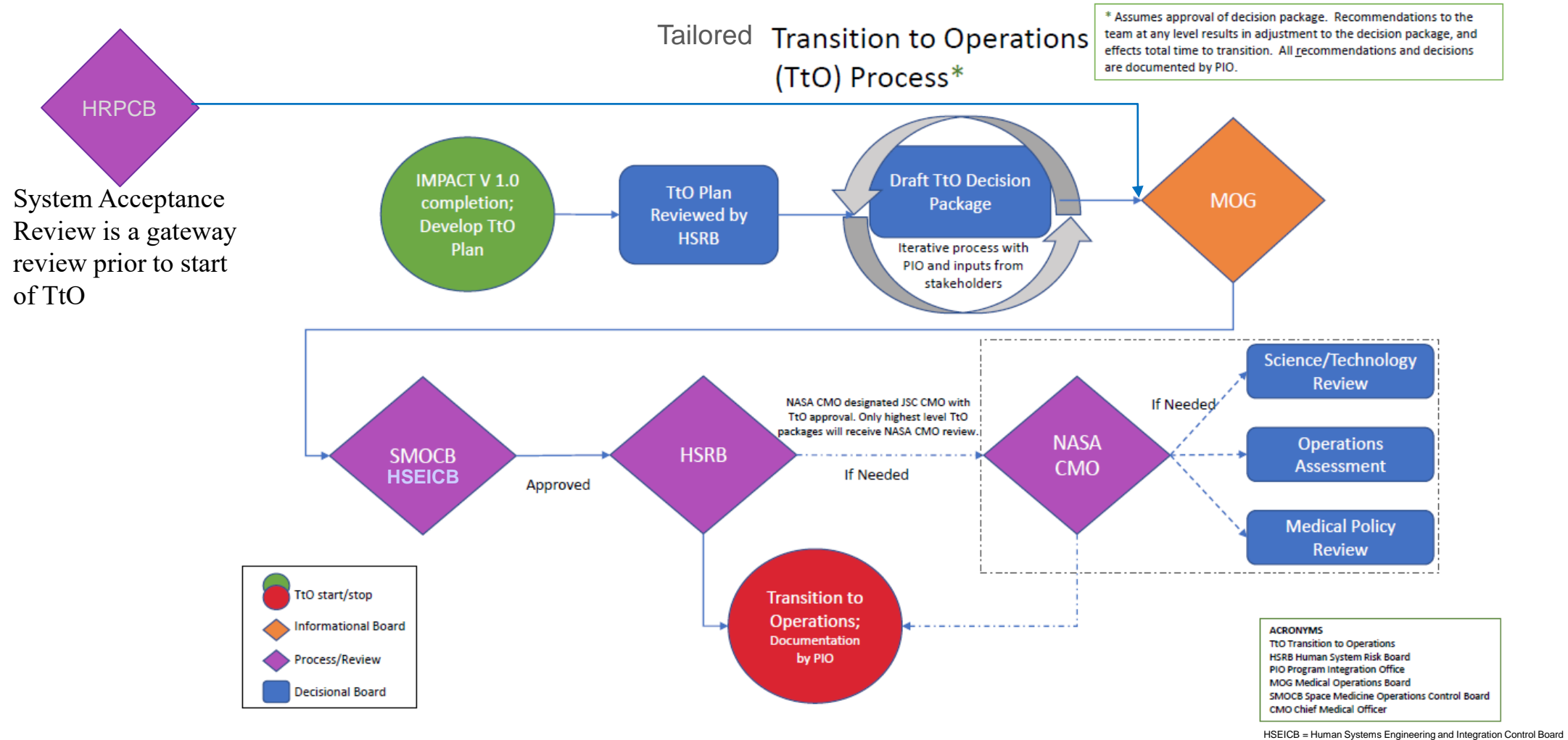
Readiness Criteria for TtO



- **IMPACT has been having working group discussions with Program Integration Office (PIO) to tailor the TtO process**
- **System Acceptance by HRP(CB) is the gateway event prior to TtO**
- **TtO proposal package complete**
 - Defined in the IMPACT TtO Plan (IMPACT-PLN-0037)
- **Receiving organization indicates readiness**
 - Operations team in place
 - Funding in place

IMPACT Tailored TtO Approval Process from NPR 8900.1B

Based on discussions with PIO



TtO is currently estimated to be a 4-6 month process, commencing April 2023

IMPACT v1.x versions will gain capability with each release



- **IMPACT v1.0 – MAR23**
 - First release for operational use
- **IMPACT v1.1 – NOV23**
 - Add deferred s/w features from v1.0
 - Fine-tuning known issues in the Evidence Library
- **IMPACT v1.2 – MAY24**
 - Segment-specific environments
 - Expanding the number of conditions on the IMPACT Conditions List (ICL)
- **IMPACT v1.x, new version every 6mos starting NOV24 (priority TBD)**
 - Conditional probabilities among conditions
 - Knowledge, skill and abilities (KSA) of crew members accounted for
 - Partial treatment weighting of resources
 - Expanding the number of conditions on the IMPACT Conditions List (ICL) further
 - Effect of RTDC availability

v1.0

MAR23

v1.1

NOV23

v1.2

MAY24

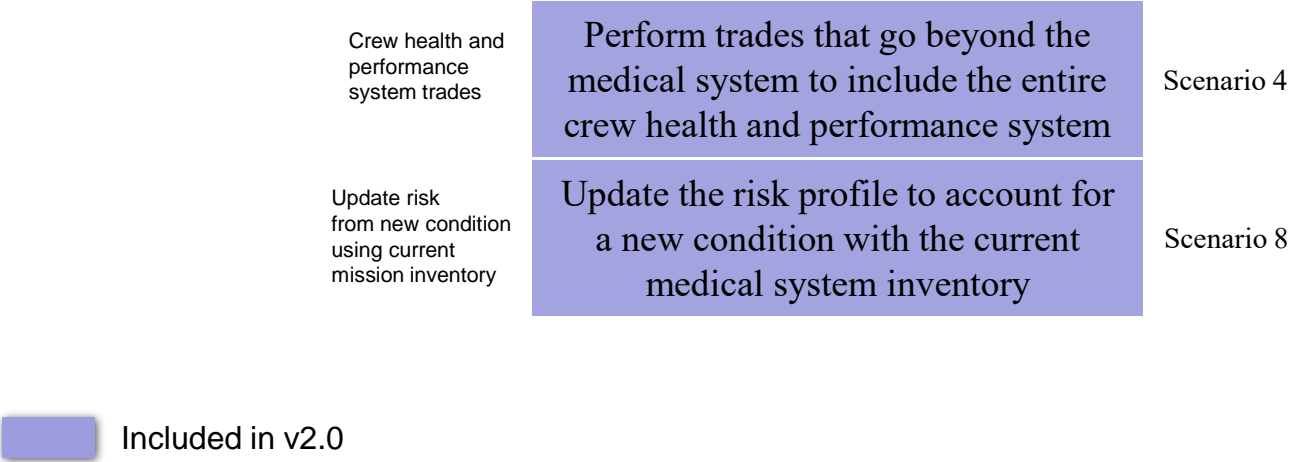
v1.x

>NOV24

Use Cases for IMPACT v2.x (aka IMPACT-CHP)



- The IMPACT ConOps scenarios defines the use cases for v2.x
- Broadening IMPACT to become a PRA and trade space tool for all Crew Health and Performance capabilities (not just medical)
- Target release ~2027



??Questions??



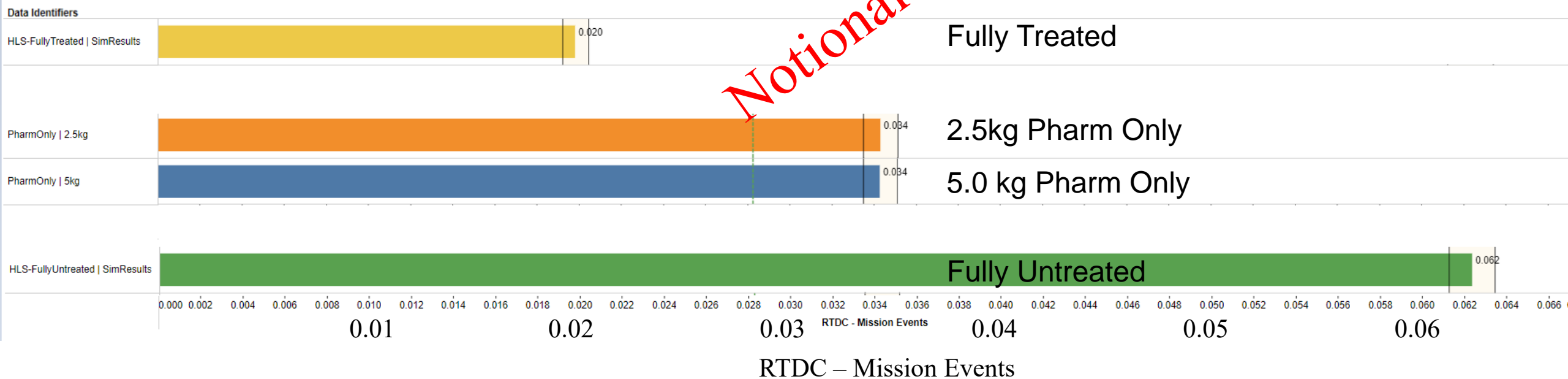
Backup slides



IMPACT v1.0 Use Cases – Comparing Medical Sets



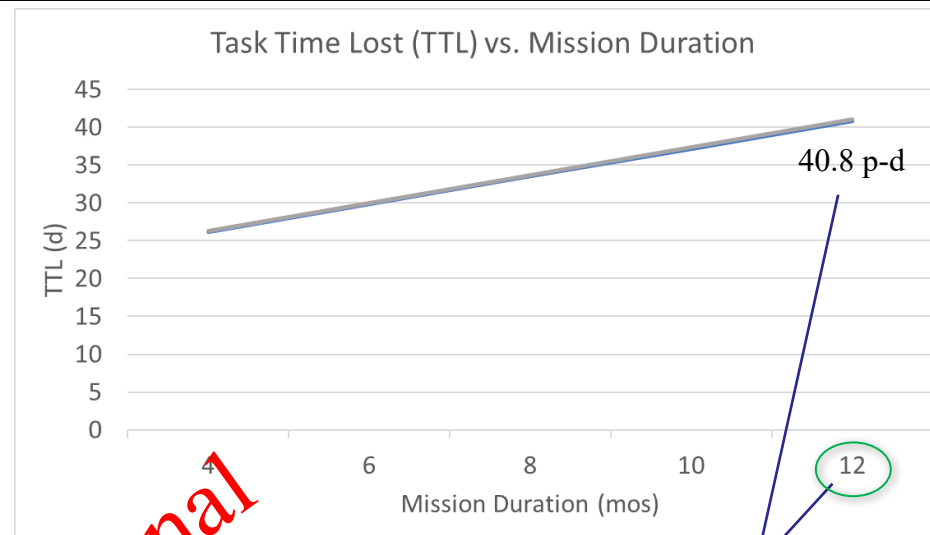
- It is often useful to determine risk factors in the Fully Treated (infinite resources) and Fully Untreated (Zero resources) cases to bound the tradespace for a given risk factor
- Two very tightly allocated medical sets (2.5kg & 5kg, pharmaceuticals only) can be compared for their effect on mitigating RTDC risk after optimization



IMPACT v1.0 Use Cases – Mission/crew trades



- **Mission attributes can be trade study variables**
 - Quantitative
 - Mission Duration
 - Number of EVAs
 - Qualitative
 - Segments added, deleted, reordered
 - Crew attributes, pre-existing conditions
- **Conditions influencing risks provides a priority listing of conditions of concern**
 - Show average contribution of each condition to the overall average risk



Notional

Condition Name	TTL - Mission (Person Day)
ICL45_Eva Related Shoulder Injury	12.153400
ICL42_Eva Related Hand Injury	5.114960
ICL100_Space Flight Associated Neuro-Ocular Syndrome (Sans)	4.630540
ICL11_Barotrauma (Ear/Sinus Block)	4.181350
ICL46_Eva Related Suit Contact Injury	3.727020
ICL110_Toxic Inhalation Exposure	2.503640
ICL39_Eva Related Decompression Sickness	1.866740
ICL95_Space Adaptation - Insomnia	0.767879
ICL97_Space Adaptation - Space Motion Sickness	0.681401